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Compound Preparation and Fabrication of Electron Beam Evoparated Cadmium Selenide (CdSe) Thin Film Solar Cells

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ABSTRACT

Highly oriented Cadmium Selenide (CdSe) thin film solar cells were fabricated on glass substrates by Electron beam evaporation technique in the vacuum about 10^{-6} torr. Cadmium Selenide (CdSe) is an important semiconductor is well suited for opto-electronic applications. The device is composed of two electrodes, Al-ZnO film as the n-type and Cu_2O films as the P-type. A thin layer of CdSe absorber was deposited by Electron beam evaporation, coating the ZnO nano structures and the entire assembly formed p-i-n junction. The deposited films were subjected to X-ray diffraction (XRD), Scanning electron microscopy (SEM) and UV-Vis measurements to study their characterizations. The interplanar distance and structural parameters were taken from X-ray diffraction (XRD) studies. The surface morphology and defect studies were done by scanning electron microscopy (SEM).The values of band gap energy and absorption coefficient were calculated by UV-Vis absorption studies. The photovoltaic characteristics were confirmed with cell structure of < Glass/Al-ZnO/nanostructured Al- ZnO/CdSe/Cu_2O >; Cadmium Selenide (CdSe) is a suitable potential candidate for developing newer photovoltaic devices.

Keywords: Cadmium Selenide, Nano structured Al-ZnO, Vacuum Evaporation, Solar cell.

1. INTRODUCTION

Cadmium Selenide (CdSe) is one of the promising semiconductor materials for high efficiency thin film photovoltaic cells as absorbing layer in manufacturing low cost thin film photovoltaic solar cell[1]. The CdSe thin films possess n-type as well as p-type semi conductivity depending upon the type of vacancies created during deposition of thin films. CdSe with a narrow direct band gap of 1.74 eV with hexagonal structure[2] and high absorption coefficient (10^4 cm^{-1}) is one of the promising candidates for quantum dot LED, photovoltaic, optoelectronic applications[3-5]. In addition, CdSe is low cost and most stable absorber material for processing of solar cell with good efficiency. Several deposition methods such as were vacuum or non-vacuum[6,7], laser ablation[8], electro chemical deposition[9], chemical deposition[10], hot wall deposition[11] and spray pyrolysis[12] employed for the deposition of CdTe thin films. The electron beam evaporation technique is suitable for the deposition of n-CdSe thin films due to high power density, wide range of controlled evaporation as well as directly evaporent material converted into vapour[13].

In the present work, we first utilized electron beam evaporation technique to fabricate p-CdSe/n-Cu_2O thin film solar cell. Electron beam evaporation is more advantage because of avoiding impurities during film growth, the tendency to form oxides can be considerably reduced and very slow rate of deposition is possible.

2. EXPERIMENTAL DETAILS

A thin film solar cell with the structure Glass/Al-ZnO/p-CdSe/ n-Cu_2O /ZnO has been fabricated in which CdSe layer was deposited on top of the Al-ZnO chemical bath coated glass substrate by electron beam evaporation technique. The thickness of CdSe layer was controlled by a quartz thickness monitor (QTM) on the evaporation equipment. Then, a layer of Cu_2O was deposited on the top of the CdSe layer by the thermal evaporation method at a pressure of 10^{-6} mbar. Finally a layer of ZnO was deposited on the top as a back contact by the thermal evaporation method. The final cell structure of the device had an area of 2x2 cm^2.

The grain size of the p-CdSe/n-Cu_2O thin films was determined by an X-ray diffractometer with Cu Kα radiation (λ = 1.5406˚ A).The optical characteristics of these films were performed by a UV/VIS/NIR spectrometer in the wavelength range from 300 nm to 1400 nm at room temperature. The surface morphology was observed by a scanning electron microscope (SEM).

3. RESULTS AND DISCUSSION

3.1 XRD analysis

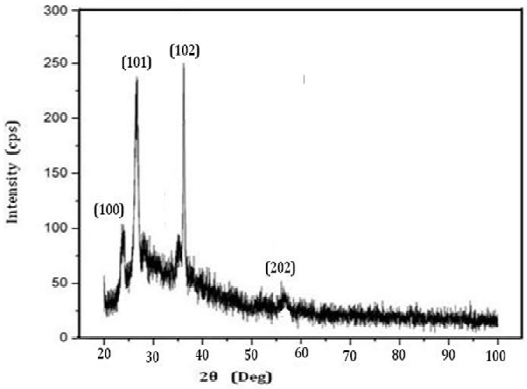


Fig.1 XRD pattern spectrum of the CdSe film

A typical X-ray diffraction pattern of CdSe thin film is shown in fig (1). The XRD pattern shows several peaks at 2θ values of 23.839°, 27.65°, 35.932°, 56.24° which may be assigned to the diffraction lines produced by the (100), (101), (102), and (202) planes of hexagonal structure. The appearance of the (102) reflection plane at diffraction angle 2θ = 35.932°and 45.36o is an indication of the hexagonal structure of CdSe thin film[14]. The appearance of many peaks in the XRD pattern is an indication of polycrystalline nature of the CdSe thin film. The crystallite size in CdSe thin film is evaluated from the intensity peaks of XRD by a Gaussian fit, using Debye- Scherrer formula,

$$D = \frac{0.98\,\lambda}{\beta Cos\,\theta} \quad (1)$$

Where, β is the full width at half maximum, **λ** is the wavelength for X-ray used and θ is the Bragg's angle.

3.2 Morphological analysis

SEM images, of p-CdSe thin film of thicknesses 25.49 KÅ, are shown in Fig.2. It has been found from Fig.2 that the films are fully covered, homogeneous, well adherent and free from crystal defects such as pin hole and cracks.

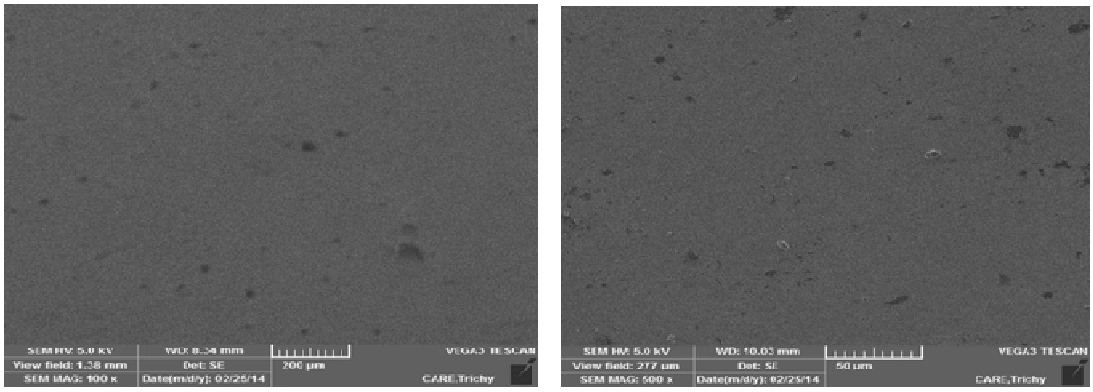


Figure 2: The SEM images of the CdSe thin film (a) 200 µm (b) 50 µm

3.3 Optical Properties

The optical absorption behavior of p-CdSe thin film is observed that all these films exhibit good optical absorption in visible range (400nm-700nm). This absorption increases with increase of film thickness due to increase of crystallite size. The bigger size of crystallite reduces the reflectivity of incident photon on the film surface and correspondingly increases absorption due to multiple reflections. The direct energy band gap Eg is obtained by extrapolating the straight portion of the curve. The intercept portion of αhν=0 line give the value of the direct band gap. The direct energy band gap of p-CdSe thin film decreases from 1.60 eV with increase of film thickness. This decrease in direct band gap with increase of film thickness is due to increase in grain size of film thickness, which can be explained on the basis of quantum size effect[15].

4. CHARACTERIZATION OF THE CELL

For the spray deposited CdSe material, the power conversion efficiency (η) of the device was relatively low (0.97%), since the data of photovoltaic parameters such as Jsc, Voc, and FF were low.

5. CONCLUSIONS

The synthesis and characterization of p-CdSe thin films deposited by Electron beam evaporation under vacuum preparative conditions have been investigated. The results clearly show the role of different preparative parameters viz purity and material quantity, substrate temperature and thickness of the deposited films in order to get good-quality photosensitive material. Structural analysis shows that the films are polycrystalline with a hexagonal crystal structure. The dislocation density and strain show a reverse nature to temperature and thickness. Micrographs show that the film surface is well covered by uniformly distributed grains with varying sizes. The observed direct band gap for optimized parameters is about 1.60 eV. The photovoltaic efficiency (0.97%) was studied with cell structure of Glass/Al-ZnO/nanostructured Al- ZnO/CdSe/Cu_2O; Cadmium Selenide (CdSe) is a suitable potential candidate for developing newer photovoltaic devices. Finally, it is concluded that the CdSe thin films are potential candidates for solar cell applications.

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